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# NASA Advanced Life Support Technology Testing and Development

IALSWG Meeting.

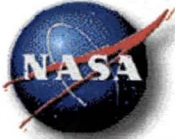
JAXA Chofu Aerospace Center, Japan, 31 Oct 2011

**Ray Wheeler**

**NASA Kennedy Space Center**

**Presentation for NASA IALSWG team, including:**

**Dan Barta, Mark Kliss, and Darrell Jan**



# Changes in NASA Advanced Life Support for 2011

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## Year 2010

### **Exploration Life Support Project**

- Syst. Integration Mod. & Analysis
- Atmosphere Revitalization
- Water Recovery
- Solid Waste Management
- Habitation Engineering

### **Thermal Control Systems Project**

### **Advanced Environmental Monitoring & Control Project**

### **Fire Prevention, Detection, & Suppression Project**

### **Radiation Protection Technologies Project**

*5 individual projects*

## Year 2011

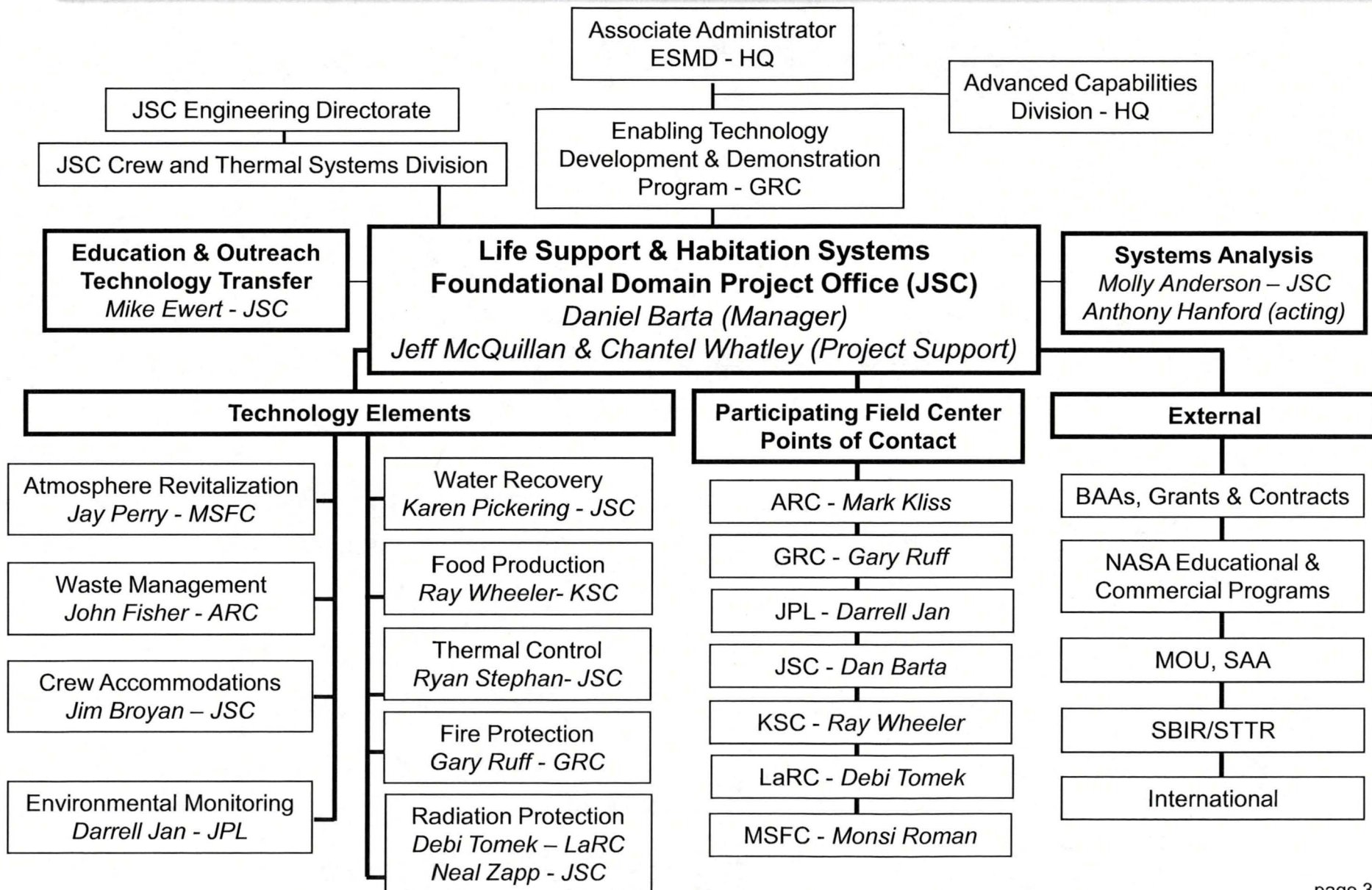
### **Life Support and Habitation Systems Foundational Domain**

- Project Analysis
- Atmosphere Revitalization
- Water Recovery
- Solid Waste Management
- Crew Accommodations
- Food Production
- Thermal Control
- Environmental Monitoring
- Fire Protection
- Radiation Protection

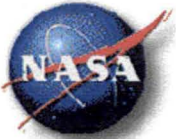
*1 consolidated project with 10 technology development elements*



# Life Support and Habitation Systems Project Management Structure (2011)







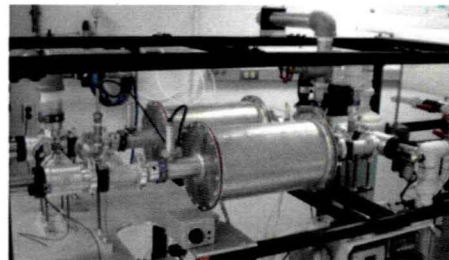
# Life Support & Habitation System: **Atmosphere Revitalization**

(NASA MSFC, JSC, ARC, KSC, GRC) Lead: Jay Perry [jay.l.perry@nasa.gov](mailto:jay.l.perry@nasa.gov)

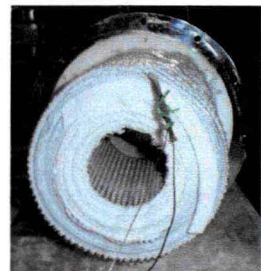
## Atmosphere Revitalization Description:

Identify and mature technologies for flexible, reliable atmosphere revitalization to enable efficient Environmental Control and Life Support.

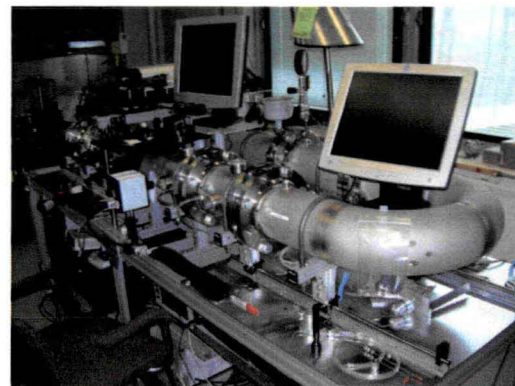
Process technology maturation tasks are conducted for water-save gas drying; trace contaminant control; CO<sub>2</sub> removal, conditioning, and reduction to useful products; particulate matter removal and disposal; atmospheric gas supply, storage, and conditioning; resource recovery, storage, conditioning, and recycling; and supporting infrastructure.



Low Power CO<sub>2</sub> Removal

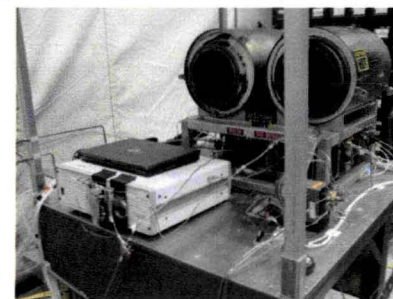


Engineered Structured Sorbents



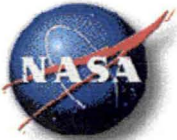
Particulate Filtration Testing Facility at NASA GRC

Milestone Title	TRL
<b>Atmosphere Revitalization</b>	
<i>Carbon Dioxide Partial Pressure Control</i>	
Low-Power CO <sub>2</sub> Removal (LPCOR) System	4 to 4+
Engineered Structured Sorbent (ESS)	4
Open Loop Regenerable CO <sub>2</sub> Removal System	4 to 4+
CAMRAS Evaluation	5+ to 6
<i>Control Trace VOC Concentrations</i>	
Advanced (alternative) Trace Contaminant Control (ATCC)	3
Photocatalytic System Development	3
<i>Particulate Matter Removal</i>	
Indexing Media Filter	3
FAST Multi-Stage Filtration System	3
Modeling of Cabin Particulate Environment	--
Test Contractor Filters	3
<i>Resource Recovery and Recycling</i>	
Closed Loop- Carbon Dioxide Reduction (CDRe)Technology	3
Co-Electrolysis	3
<i>Gas Storage and Recycling</i>	
Subcritical Liquid Storage	2 to 3
Scavenging of Oxygen from Gaseous Mixture	2 to 3



Horizontal Bosch Test Stand at MSFC.



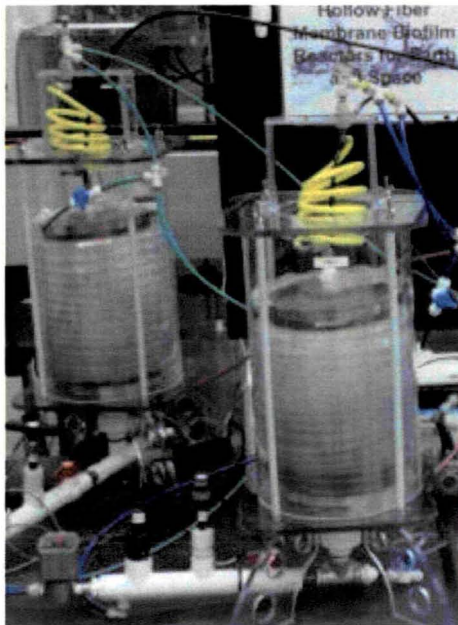


# Life Support & Habitation Systems: **Water Recovery**

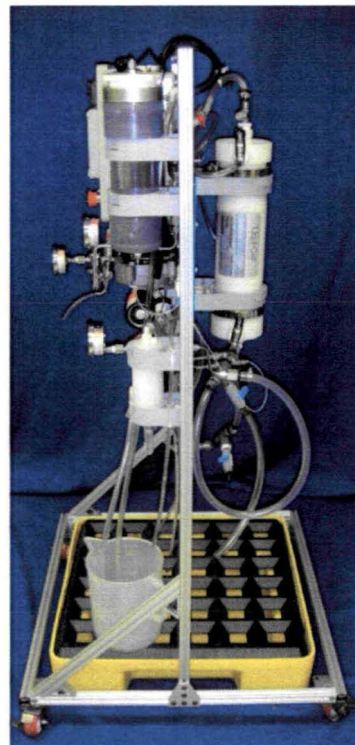
(NASA JSC, ARC, MFC, KSC, GRC) Lead: Karen Pickering [karen.d.pickering@nasa.gov](mailto:karen.d.pickering@nasa.gov)

## Water Recovery Description:

Enable long duration missions by increasing the percent closure of the water loop and reducing consumable cost for water recovery. Reliable primary treatment systems, technologies to recover water from brine, and improved wastewater stabilization and disinfection systems are among the major areas of interest for technology development.

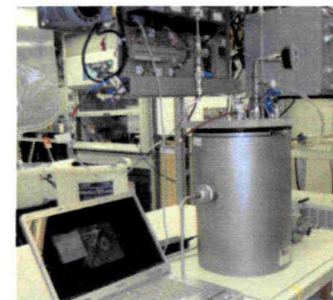


5 Biological Treatment of Wastewater



Osmotic Distillation

Milestone Title	TRL
<b>Water Recovery</b>	
<i>Wastewater Composition and Storage Systems</i>	
Test Contractor Filters	3
Stabilization and Composition Assessment	3
Wastewater Storage	3
<i>Primary Processing</i>	
Osmotic Distillation (OD) System Development	4
Direct Osmotic Concentration (DOC) Evaluation	4
Cascade Distillation Subsystem (CDS) Development	5
Vapor Compression Distillation (VCD) Development	6
<i>Post-processing, Disinfection &amp; Potable Water Storage</i>	
Biocide and Antimicrobial Technology	3 to 4
Thermal Catalyst Development	3
Processed Water Polishing	--
<i>Water Recovery from Brine Systems</i>	
Brine Membrane Enclosure for Heat Melt Compactor	4
Brine Residual In-Containment (BRIC)	2
<i>Water Recovery Systems</i>	
Radiation Water Wall Concept	--



Brine Residual in Containment (BRIC) Test Stand





# Life Support & Habitation System: **Waste Management**

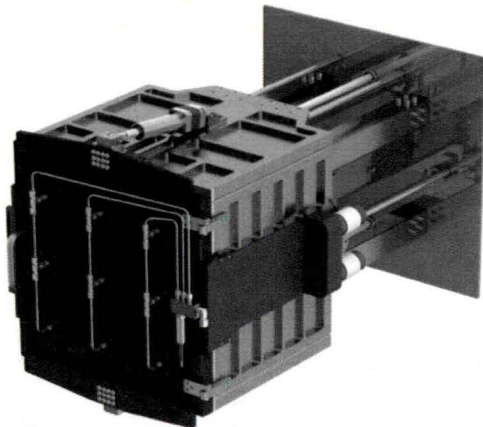
(NASA ARC, KSC) Lead: John Fisher [john.w.fisher@nasa.gov](mailto:john.w.fisher@nasa.gov)

## Waste Management Description:

Recover resources, increase crew safety and performance, and protect planetary surfaces while decreasing mission cost. Technology gaps to be addressed for future missions include:

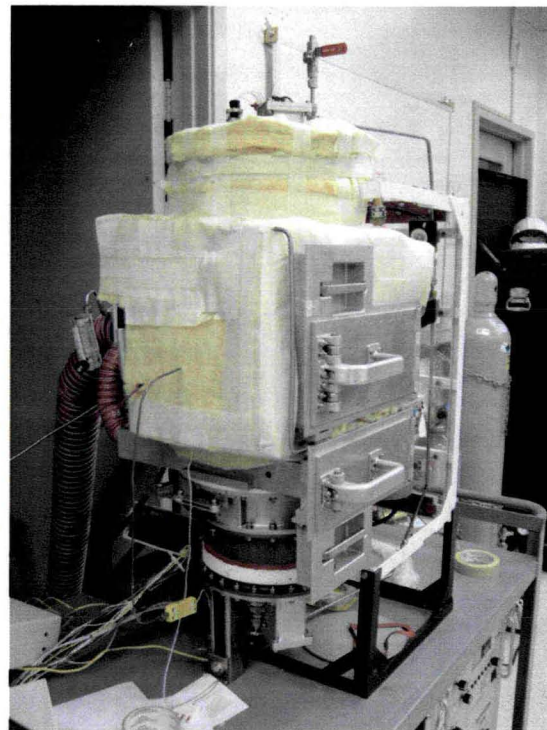
- Water/resource recovery for cost savings
- Safening and stabilization
- Disposal and containment,
- Waste/trash volume reduction,
- Waste collection, and odor control.

Milestone Title	TRL
<b>Waste Management</b>	
<i>Volume Reduction</i>	
Heat Melt Compaction (HMC)	4
<i>Waste Stabilization &amp; Storage</i>	
Microbial Characterization of Solid Wastes	--



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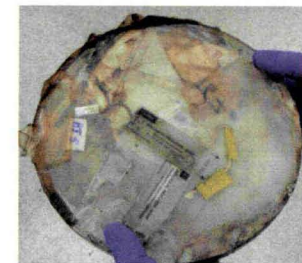
Plastic Melt Waste Compactor  
Phase II Design



The First Generation Heat Melt Compactor

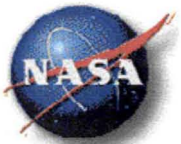


Shuttle waste "footballs".



Shuttle waste was compacted in the HMC to make flat circular tiles.





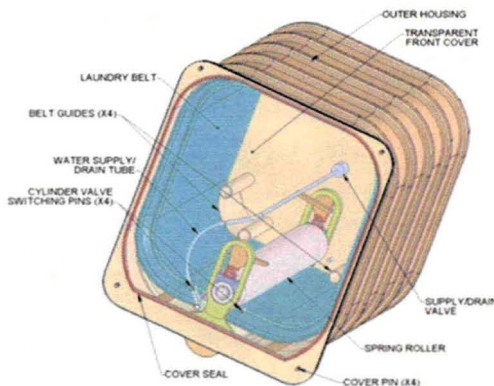
# Life Support & Habitation Systems: **Crew Accommodations**

(NASA JSC) Lead: Jim Broyan [james.l.broyan@nasa.gov](mailto:james.l.broyan@nasa.gov)

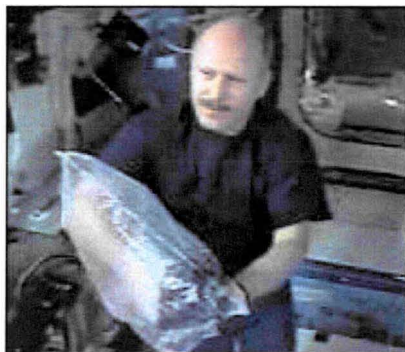
## Crew Accommodations Description:

Focus on crew interfaces with vehicle systems (hygiene, metabolic waste, food preparation), internal deployable crew volumes/interfaces, impacts of vehicle systems on habitable volume (acoustically quiet interiors, odors), clothing/laundry, conversion of logistics byproducts to resources, and advanced mission analogs for habitation validation.

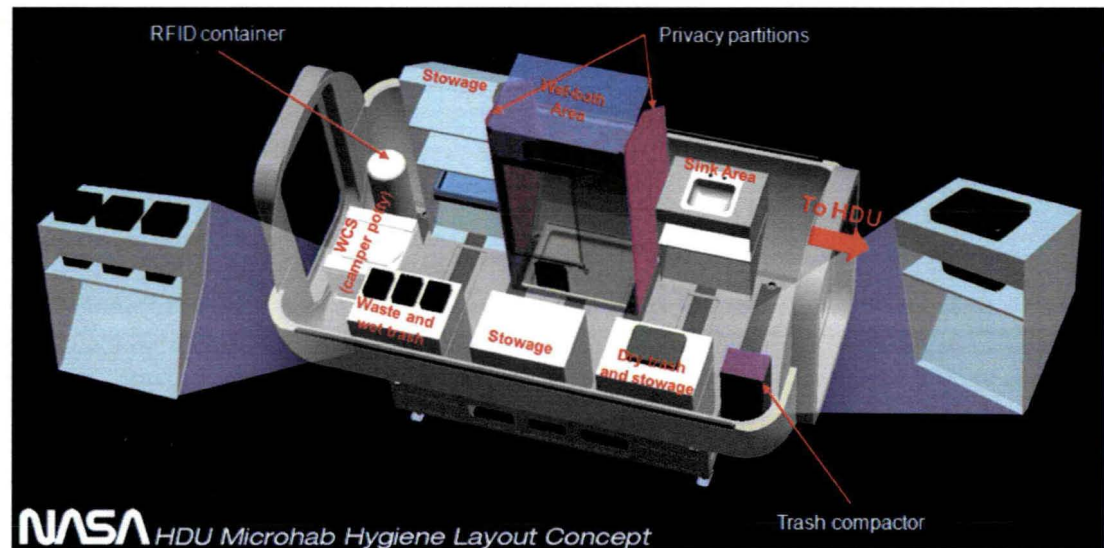
Milestone Title	TRL
<b>Crew Accommodations</b>	
<i>Habitability Outfitting</i>	
Habitability Outfitting Integration	2
<i>Clothing Laundry</i>	
Clothing Logistics Reduction Technology	2



Innocent Simple Laundry Concept – fixed roller wringer that is spring loaded to provide agitation and drainage.



Expedition 6 Commander Bowersox Washed Clothes Using a Plastic Bag



NASA HDU Microhab Hygiene Layout Concept





# Life Support & Habitation Systems: **Food Production**

(NASA KSC) Lead: Ray Wheeler [raymond.m.wheeler@nasa.gov](mailto:raymond.m.wheeler@nasa.gov)

## Food Production Description:

Initial implementation of food production could provide the capability to grow vegetables and fruits to augment the crew's diet of packaged foods. These fresh foods will add texture, flavor, and variety to the diet and provide bio-available nutrients, which can serve as a radiation countermeasure. Expanded food production systems for future missions will reduce the need for stowed foods and contribute to CO<sub>2</sub> removal/reduction, O<sub>2</sub> production, and water recycling.

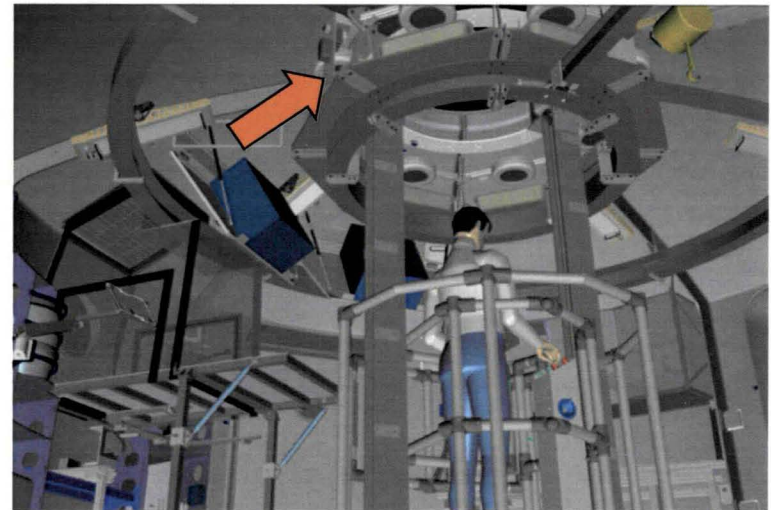


Red-leaf lettuce plants growing in rooting pillows compatible with the  $\mu$ -g VEGGIE plant growth unit. Roots take up water through a porous nylon membrane.

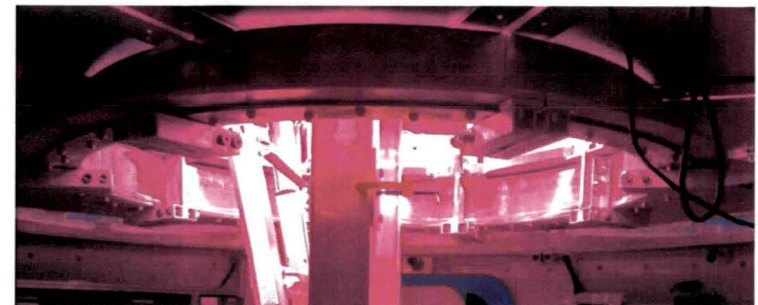


VEGGIE plant growth unit.

Milestone Title	TRL
Food Production	
<i>Crop Production</i>	
Crop Production Hardware and Concepts	3



Plant growth trays with circular LED light fixtures above each tray located in the Food Production Atrium for the Habitat Demonstration Unit (HDU).





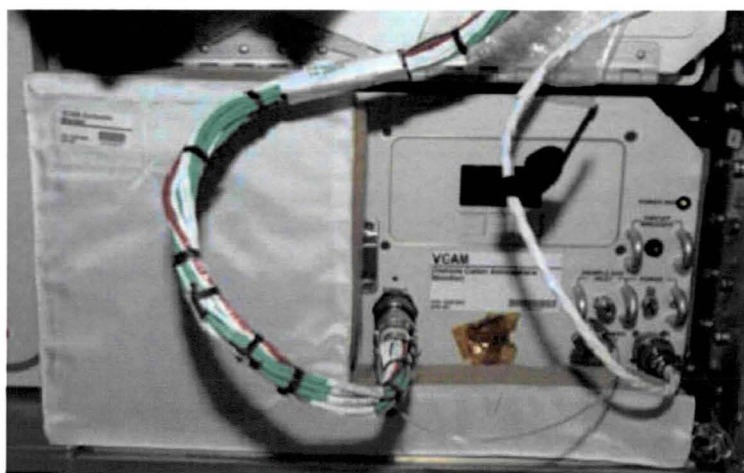


# Life Support & Habitation Systems: **Environmental Monitoring**

(NASA JPL, JSC, GRC, MSFC) Lead: Darrell Jan [darrell.l.jan@jpl.nasa.gov](mailto:darrell.l.jan@jpl.nasa.gov)

## Environmental Monitoring Description:

- To develop miniature chemical and biological monitors, leveraging the rapidly progressing technical community. The overarching goal is to assure, within allocated resources, that suitable environmental monitoring systems will be provided for future crewed NASA vehicles and habitats, for both nearer term and longer term missions. Such monitoring systems will be responsive to needs based directly on crew health as well as other vehicle systems.

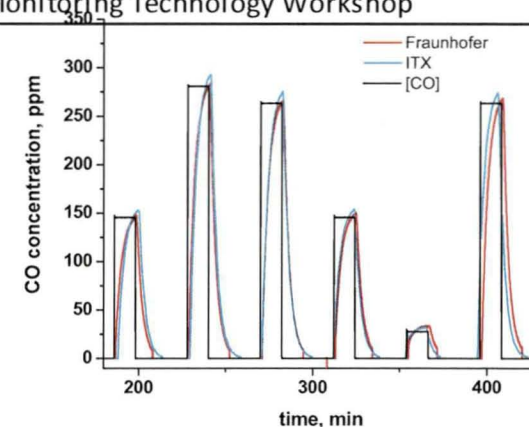


<sup>9</sup> Vehicle Cabin Atmosphere Monitor (VCAM) installed on ISS Express Rack



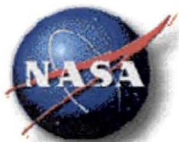
Sionex microAnalyzer for evaluation

Milestone Title	TRL
<b>Environmental Monitoring</b>	
<i>Atmosphere Monitoring</i>	
Particulate Monitor - Optical Particle Counter (OPC)	2 to 3
Particulate Monitor - Charge-Based Detector (CBD)	2 to 3
Atmosphere Monitoring Technology Evaluation	--
TELS Technology Evaluation	3
Environmental Factors Air Contaminants Support	--
<i>Water Monitoring</i>	
Water Monitoring Technology Evaluation	--
Water Sample Input to Mass Spectrometer	--
Water Contaminants Support	--
<i>Microbial Monitoring</i>	
Microbial Monitoring	--
Microbial Monitoring Technology Assessment	--
Microbial Monitoring Technology Workshop	--



Comparison of ITX and Fraunhofer response to CO at 15,000 ppm of H<sub>2</sub>O (~40% RH)





# Life Support & Habitation Systems: **Thermal Control**

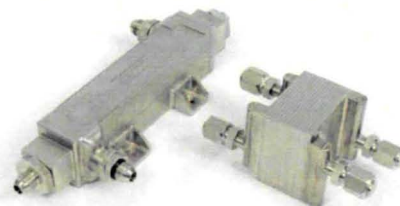
(NASA JSC, GRC, JPL) Lead: Ryan Stephan [ryan.a.stephan@nasa.gov](mailto:ryan.a.stephan@nasa.gov)

## Thermal Control Description:

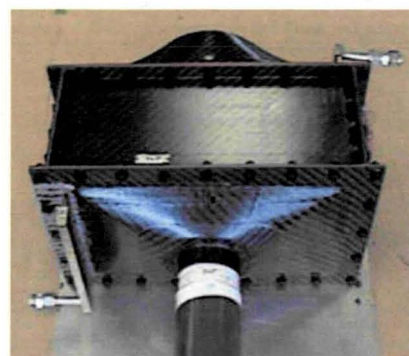
Use a rigorous technology development process to advance the state of the art in thermal control hardware by reducing hardware mass and improving hardware reliability, useful life, reducing volume, and improving thermal performance. An effective thermal control system must provide three basic functions to a vehicle design: heat acquisition, heat transport, and heat rejection. The thermal control element will focus on addressing key technologies germane to these three functions.



Fluids Life Test Stand



Microchannel Heat Exchanger



Composite air/liquid Heat Exchanger

Milestone Title	TRL
<b>Thermal Control</b>	
<i>Heat Transport</i>	
Thermal Control System Fluids Life Test	--
<i>Heat Rejection</i>	
Radiator Dust Assessment and Mitigation	--
Integrated Radiator PCM Development	4 to 5
Variable Heat Rejection Radiator: Digital Radiator	4
Integrated Radiator Phase Change Material (PCM) Development	4 to 5
Transient Sublimator	3
Freezable Radiator	3
Electrochromic Radiator	3
Flow Through Phase Change Material (PCM) Module	3 to 4
<i>Heat Acquisition</i>	
Composite Heat Exchangers	4 to 5
Microchannel Heat Exchanger	5 to 6

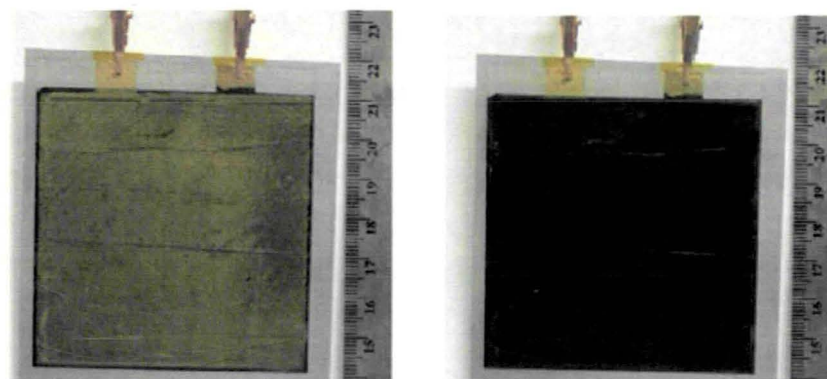
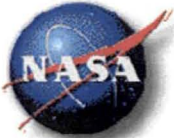


Figure 2. Electrochromics Showing Active Switching Area from Gold to Black

Electrochromic Radiator





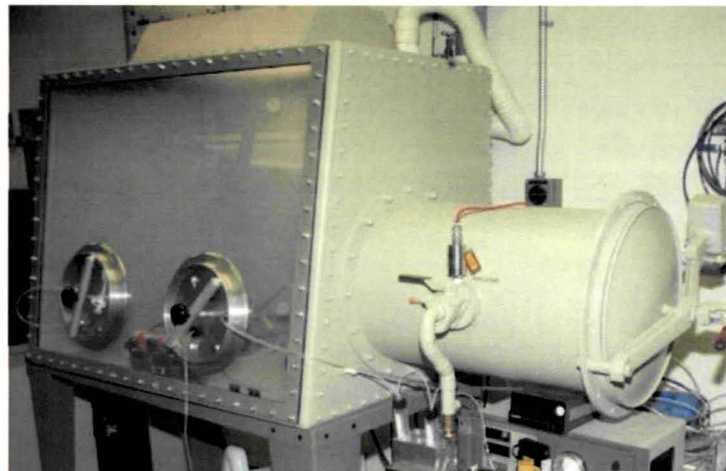
# Life Support & Habitation Systems: **Fire Protection**

(NASA Glenn Research Center and JSC) Lead: Gary Ruff [gary.a.ruff@nasa.gov](mailto:gary.a.ruff@nasa.gov)

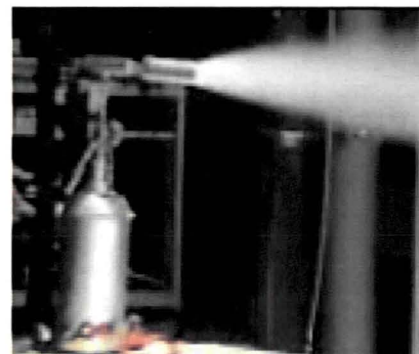
## Fire Protection Description:

- To develop and mature technologies that will ensure crew health and safety on exploration missions by reducing the likelihood of a fire or, if one does occur, minimizing the risk to the crew, mission, or system. This is accomplished through the development of hardware, design rules and requirements, and procedures that enhance fire safety in exploration vehicles and habitats by addressing the areas of (1) fire prevention and material flammability, (2) fire signatures and detection, (3) fire detector (gaseous and particulate detector) development, and (4) fire suppression and post-fire response.

Milestone Title	TRL
<b>Fire Protection</b>	
<i>Material Flammability and Ignition</i>	
Flammability Assessments in Spacecraft Atmosphere	--
Modeling of NASA-STD-6001B Test 1	--
Fire Safety Demo Formulation	--
Testing at White Sands Test Facility (WSTF)	--
<i>Fire Detection</i>	
Gaseous Detector Development	--
Particulate Detector Development	--
Fire Detector Testing	5
<i>Fire Suppression</i>	
Fire Suppression Technology Development	5
<i>Post-Fire Recovery</i>	
Post-fire Monitoring and Response	3
Post-fire Cleanup	--



<sup>11</sup>Exposure chamber for fire detection

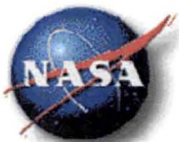


Early prototype water mist fire extinguisher

### **Portable Combustion Product Monitoring System.**

Sensors for high and low-concentrations of CO, CO<sub>2</sub>, hydrocarbons, O<sub>2</sub>, and H<sub>2</sub>.





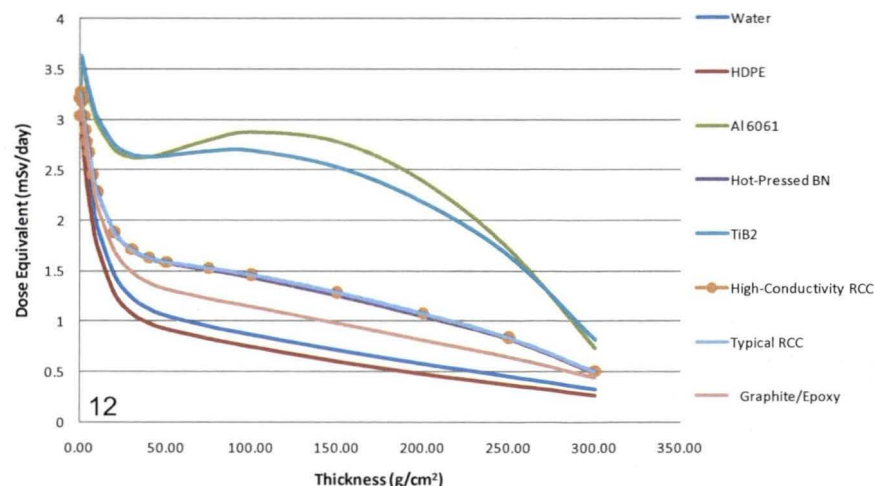
# Life Support & Habitation Systems: **Radiation Protection**

(NASA LaRC, GRC, ARC, MSFC, JSC) Lead: Debi Tomek [deborah.m.tomek@nasa.gov](mailto:deborah.m.tomek@nasa.gov)

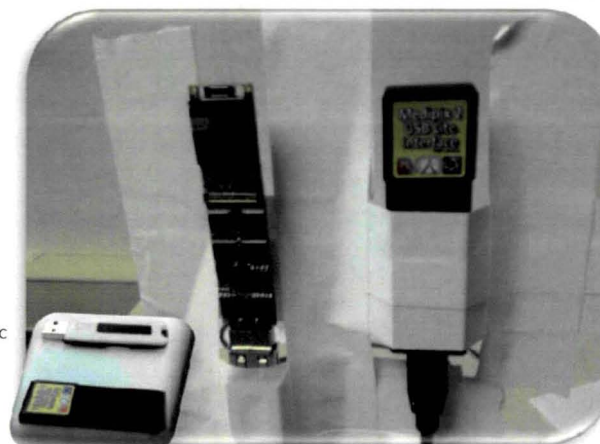
## Radiation Protection Description:

- Identify, develop and demonstrate radiation protection technologies that enable space exploration beyond LEO.
- Test the feasibility of existing concepts, and also develop new concepts, to protect astronaut crews and hardware from the harmful effects of radiation, both in low Earth orbit and while conducting long-term missions away from Earth.
- Mature radiation monitoring technologies to Technology Readiness Level (TRL) 6. Hand-off from Human Research Program (HRP) measurement technologies for maturation.
- Ensure appropriate communication, coordination, and exchange of information between the various diverse and distributed Radiation functions within the Agency.

Materials Comparison, Dose Equivalent vs. Thickness,  
1977 Solar Min GCR



Milestone Title
<b>Radiation Protection</b>
<i>Radiation Shielding</i>
Update of Material Database, Metric lists, and Downselect
Specimen Development, Fabrication and Testing
Instrumentation
Analysis
<i>Dosimetry and Monitoring</i>
Miniaturized Tissue Equivalent Monitors
Miniaturized Personal Monitor
<i>Models &amp; Tools</i>
Development, validation and warning systems
<i>Radiation Protection Systems</i>
Model Integration

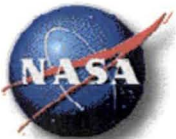


Medipix Engineering Units Tested at NASA  
Space Radiation Laboratory (NSRL)



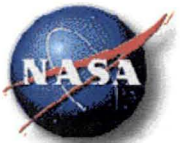
Cargo Bag –  
Repurposing for Use  
as Radiation Shielding



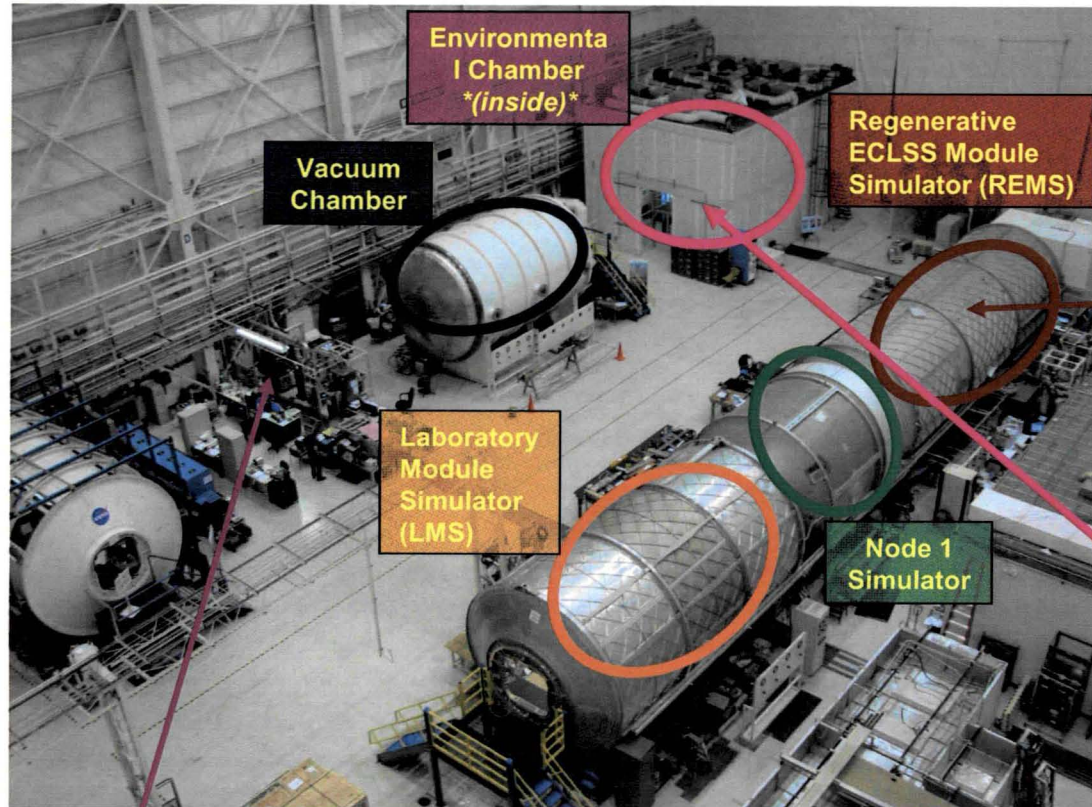


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## NASA Advanced Exploration Systems (AES) Projects with Advanced Life Support Themes



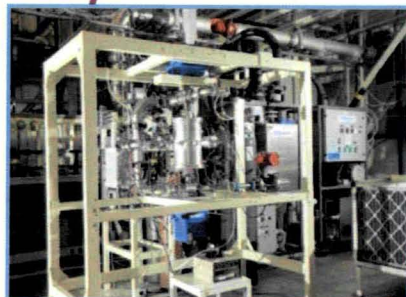
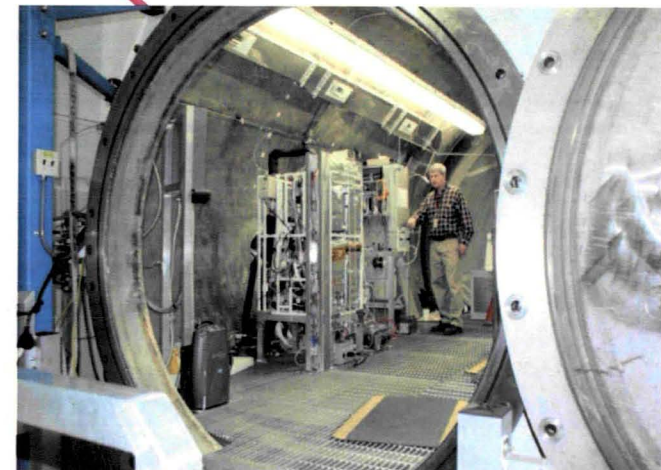
# AES Atmosphere Revitalization Systems and Environmental Monitoring Systems (Monsi Roman, Lead [monsi.roman@nasa.gov](mailto:monsi.roman@nasa.gov) )



'Humans in the Loop' Generating Metabolic Waste in the REMS



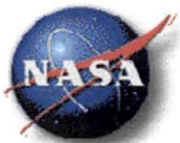
Integrated ARS Testing Chamber



Test Bed at NAS Marshall Space Flight Center

ARS Subsystem Testing Area





# AES Atmosphere Revitalization Systems and Environmental Monitoring Systems *(continued)*

## ➤ Carbon Dioxide Removal

- SOA: ISS carbon dioxide removal assembly (CDRA)
  - CO<sub>2</sub> sorbents to improve reliability
  - Open loop CO<sub>2</sub> removal concepts that use either immobilized amine or mixed zeolite sorbents that can potentially replace the CO<sub>2</sub> removal beds in a CDRA-like process
  - Energy-efficient structured sorbents and other alternative sorbents as well as membrane
  - Cabin and ventilation system interface issues, including interface issues with a vehicle suit loop will be investigated.



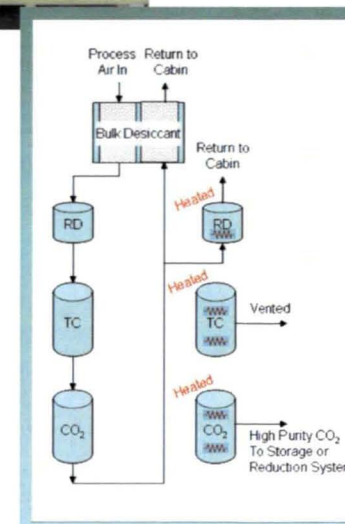
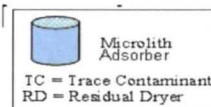
## ➤ Oxygen Recovery

- Oxygen generation SOA: ISS oxygen generation assembly (OGA)
  - Investigate robust, reliable water electrolysis cell stack that addresses issues
  - Oxygen drying and compression options, both temperature swing adsorption-based and mechanical compressor-based, will be considered.
- CO<sub>2</sub> Reduction SOA: None
  - Plasma methane pyrolysis, the leading methods for recovering additional hydrogen from ISS Sabatier process waste methane will be evaluated.
  - Methods for handling hydrogen within the OGA-Sabatier-methane post-processing string will be investigated.



## ➤ Trace Contaminant Control

- SOA: ISS Trace Contaminant Control (TCC) System
  - Assess adsorbent media and catalysts; best will be applied to an ISS-derived TCC
  - Integration of TCC equipment with CO<sub>2</sub> removal
  - Development of photocatalytic oxidation processes to niche applications that reduce volatile organic loading in humidity condensate will be conducted to alleviate the logistics penalty associated with this phenomenon as of aboard the ISS.





# AES Atmosphere Revitalization Systems and Environmental Monitoring Systems *(continued)*

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## ➤ **Environmental Monitoring**

- The best performing atmospheric monitoring candidates demonstrated on board the ISS to date will be operated in tandem to determine the best suite of instruments necessary to provide vehicle operational autonomy necessary for deep exploration missions. Monitoring instrument recommendations will be submitted to the ISS Program to improve functional autonomy and reduce reliance on assessing cabin air quality using grab samples that rely on ground analysis and logistics between Earth and orbit. Early warning instruments targeting specific analytical targets will be demonstrated. Extending air quality instrument function to include front-end processors to allow for volatile organic monitoring in potable water will be demonstrated.
- Microbial monitoring techniques for both airborne and waterborne loads will be demonstrated.

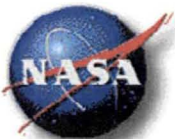
## ➤ **Systems Analysis & Simulation**

- ECLS System architectures, process technology models, and functional trade assessments will be conducted to support and refine the test and evaluation activities through the duration of the project.

## ➤ **Validation and Testing**

- Performance testing to characterize targeted ECLS system process technology, validate process technology models, and simulate technical product performance on board the ISS and application to deep space exploration vehicles and habitats will be conducted. The testing and validation will occur at varying degrees of complexity starting at the component level up to the fully integrated subsystem level.





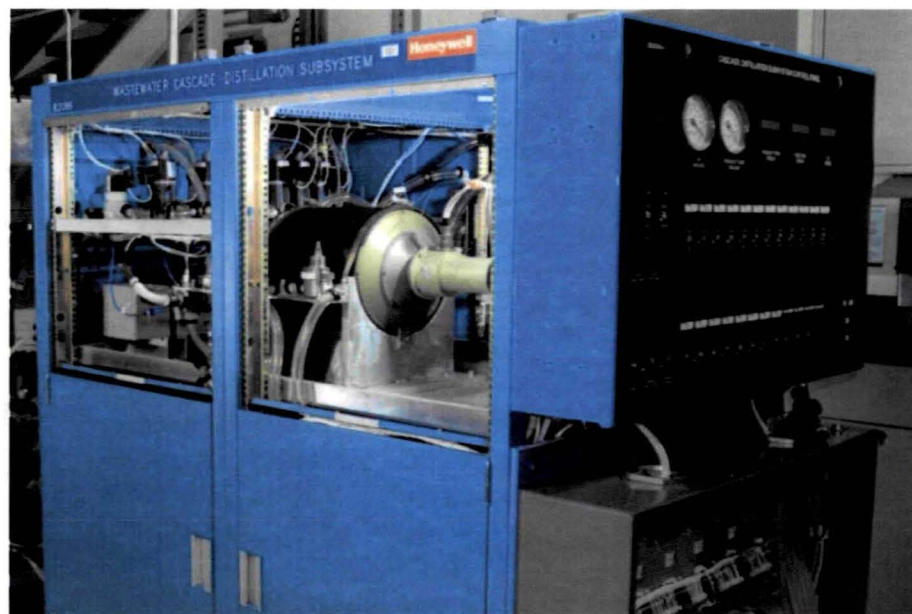
# Water Processing and Waste Recovery from Solids

(Derek Neumeyer, Lead, [derek.j.neumeyer@nasa.gov](mailto:derek.j.neumeyer@nasa.gov) )

- **Cascade Distillation System (CDS):**

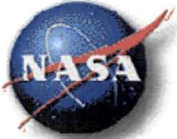
- The initial primary processor to be matured is cascade distillation technology, developed by Honeywell, Inc. Cascade distillation is a multistage vacuum distillation process that has energy and reliability advantages over the current SOA. Through the course of this work, the existing distiller will be redesigned to incorporate sealed bearings and improve on-orbit servicing capability, and a new thermoelectric heat pump will be built. These components will ultimately be delivered to JSC, where they will be integrated into a complete subsystem, which includes controls development, for integrated testing.

*Cascade Distillation  
System (CDS)  
in test stand*



- **Water Stabilization:**

- Alternate stabilization options that increase ground processing team as well as flight crew safety and the reliability of system operation will be tested within the cascade distillation system at JSC in the FY12 to FY13 time frame. Furthermore, biological methods of wastewater stabilization will be integrated into testing during FY14.

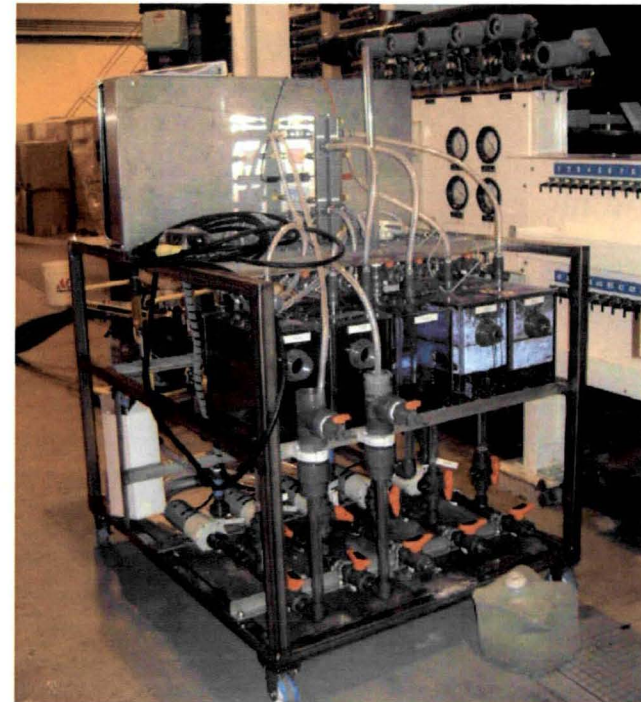


# NASA AES Water Processing Waste Recovery from Solids

(Continued)

## Electrodialysis Metathesis (EDM) :

- The EDM approach will test a commercially available version of the processor using a simulated feed stream. This test unit will be leased from the current owner, Veolia Water Inc. The lease will include a test cell and expertise in the installation and operation of the system. The leased unit will be scaled down from this system to a size appropriate to accommodate the lower spacecraft flow requirements. The system will be tested on human urine that has been concentrated in a wiped-film rotating-disk distillation system, which is essentially the same as the CDS and UPA in function. The EDM will be shipped to JSC and integrated with the CDS system for additional integrated testing.



EDM Large Scale Test Stand





# NASA AES Logistics Reduction and Repurposing

(James Broyan, Lead, [james.l.broyan@nasa.gov](mailto:james.l.broyan@nasa.gov) )

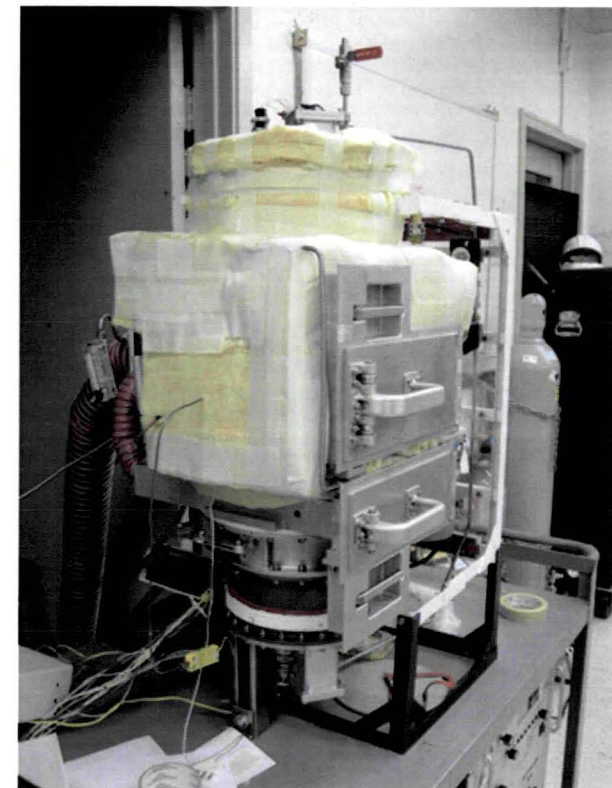
## Heat Melt Compactor

- Products / Content: Develop a 2<sup>nd</sup> Generation Heat Melt Compactor (HMC)
- Compacting waste materials and producing dry, sterilized, plastic encapsulated, low volume tiles for storage, disposal, or radiation protection.
- This gap filling technology will be designed for high reliability, commonality and interoperability with life support system elements to support multiple mission applications.
- Characterize air and water byproducts as ECLSS inputs
- The HMC will be advanced from TRL 4 to 6, and a high fidelity unit will be produced for future use in an integrated ground test bed.



Example of volume reduction  
/stable tile for mixed trash

1<sup>st</sup> Generation  
Proof of concept  
Heat Melt  
Compactor





# NASA AES Logistics Reduction and Repurposing *(continued)*

## Trash to Supply Gas

- **Products / Content:** This activity will look at promising lower TRL technologies that process waste (trash & human waste) all the way to gases, which can be reused, thus saving other logistics which must be supplied. **Methane, hydrogen and oxygen** are all candidates for use in propulsion. Hydrogen and oxygen can also be reused for ECLSS. The Waste Reuse Systems Engineering Analysis task will guide the testing and selection of these technologies, which will come primarily from SBIR and other past work.
- Technologies include:
  - Incineration
  - Pyrolysis
  - Gasification
  - Syn-fuel processes







# NASA AES Logistics Reduction and Repurposing *(continued)*

## Logistics to Living Concepts

- **Products / Content:** Long duration missions will require large amounts of volume for logistics due to the inability to resupply. LTL is defined as repurposing or converting logistical items (containers, foam, components, etc...) into useful crew items or life support augmentation on-orbit after they have provided their primary logistics function.
  - Currently a substantial amount of all logistics supplies are packaging mass. For a six-month mission, a crew of 4 might need over 200 cargo transfer bag (CTB) equivalents.
  - The intent is that by repurposing items, dedicated crew items do not have to be launched and overall launch mass is decreased.
- **Plan:** Reuse all logistical items based on systems analysis recommendations.
  - Develop multiple purpose **unfolding CTB** elements to derive a variety of dual-use outfitting elements for furniture, partitions, doors, acoustical treatments, etc.
  - Deploy logistics and HMC tiles for **radiation shielding**.
  - Develop **water wall concepts** where CTBs can be double-walled to fill with water. May eventually include passive processing of wastewater.
  - **Test** various LTL technologies in DSH and other field **analog**s.

